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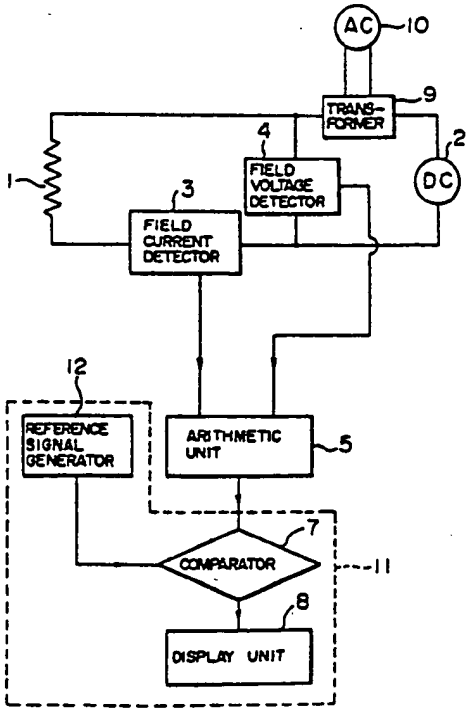
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(54) Fault diagnosis system for rotor winding of rotary electric machine.

(57) A fault diagnosis system for a rotor winding of rotary electric machines is disclosed, in which the rotor winding of rotary field type (1) is excited in DC fashion by an excitation circuit (2, 3, 4, 9), on which an AC voltage is superposed, the impedance of the rotor winding (1) is calculated from the current and voltage of the AC portion flowing in the rotor winding (1), and the resulting impedance is compared with a reference impedance thereby to decide a fault, if any, of the rotor winding (1), thus making possible accurate diagnosis of a rotary electric machine even while it is running.

FIG. 1



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FAULT DIAGNOSIS SYSTEM FOR ROTOR WINDING OF ROTARY ELECTRIC MACHINE

BACKGROUND OF THE INVENTION

The present invention relates to a fault diagnosis system for a rotor winding of a rotary electric machine such as a large-capacity turbine generator, or more in particular to a rotor winding fault diagnosis system suitable for detecting inter-layer shorting of the rotor winding.

Conventional rotor winding fault diagnosis systems of this type generally used in the past, as one of such examples is disclosed in U.S. Patent No. 4,377,784 or JP-A-58-12555, comprises a magnetic flux detector for detecting the magnetic fluxes generated in proximity of the surface of the rotor thereby to determine whether the rotor winding is in fault or not.

In these conventional rotor winding fault diagnosis systems, however, a magnetic flux detector is required to be projected into the rotary machine for continuous monitor, and therefore the problem of damage during rotation or heating under high magnetic field is posed, resulting in a low reliability in long operation. In cases other than continuous operation, the magnetic flux detector is inserted into the rotary electric machine while the rotor is rotating, thus giving rise to a danger of contact between the rotor and the magnetic flux detector. Further, in a rotary electric machine of hydrogen-cooling type so constructed that a magnetic flux detector is inserted from outside the machine, the insertion work is difficult as hydrogen is sealed inside.

In order to solve these problems, a rotor winding fault diagnosis system shown in Fig. 2 has been suggested by the same inventor as those of the present invention. As shown in Fig. 2, a field winding 1 is supplied with a field current from excitation means 2, and the system further comprises a field current detector 3 and a field voltage detector 4. The field current I detected at the field current detector 3 and the field voltage V detected at the field voltage detector 4 are used to calculate the field resistance $R_t = V/I$ at a given time point t by an arithmetic unit 5. This field resistance R_t is stored in a memory, while a field resistance $R_{t-\Delta t}$ stored a predetermined time Δt before the time point t is produced from a memory 6, and is compared with the field resistance R_t. If the absolute value of the difference between them is larger than a predetermined value ΔR, a signal is produced as an alarm from a comparator 7. The alarm signal thus produced from the comparator 7 is displayed on a display unit 8.

In this configuration for comparing th field resistance R_t at a given tim point t with the field resistance $R_{t-\Delta t}$ at a time point $t - \Delta t$, if a fault such as an inter-layer shorting occurs in the field winding 1 during the time period Δt, the field resistance $R_{t-\Delta t} = 0.5$ ohm at a time point $t - \Delta t$ becomes $R_t = 0.4$ ohm at the time point t, for example. As a result, the absolute value of the difference between the field resistor $R_{t-\Delta t}$ and the field resistance R_t becomes 0.1 ohm. Assume that the value ΔR is set to 0.05 ohm.

Then,

$$R_t - (R_t - \Delta t) > \Delta R \quad \text{..... (1)}$$

An alarm signal is thus produced from the comparator 7, and a fault is indicated on the display unit 8.

If the field winding 1 is disconnected, on the other hand, the field resistance $R_{t-\Delta t}$ at time point $t - \Delta t$ becomes $R_t = \infty\Omega$ at time point t. As a consequence, the absolute value of the differenc between the two field resistances is $\infty\Omega$. Therefore, if the value ΔR is set at 0.05 ohm,

$$R_t - (R_t - \Delta t) > R \quad \text{..... (2)}$$

The comparator 7 thus produces an alarm signal with a fault indicated on the display unit 8.

In this way, such a fault as an inter-layer shorting or disconnection of the rotor winding is detected by the field current detector 3 and the field voltage detector 4 installed outside of the rotary electric machine on the one hand, and if the value ΔR is set properly, it is possible to diagnose a fault of the rotor winding without being affected by the faulty operation due to noises or the change in field resistance due to temperature increase of the field winding on the other.

The above-described conventional rotor winding fault diagnosis systems in which a fault is detected by the winding resistance of the rotor winding, however, has the disadvantage that if an inter-layer shorting occurs in the rotor winding, for instance, the difference between the winding resistance before and after occurrence of the inter-layer shorting of the rotor winding is very much decreased to an undetectable extent in the case of a great number of turns of the rotor winding involved, so that applications of the diagnosis system are limited.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a fault diagnosis system for a rotor winding of a rotary electric machine which is capable of detecting an inter-layer shorting of the rotor winding with high accuracy even during operation.

In order to achieve the above-mentioned object, there is provided according to the present invention a fault diagnosis system comprising a power supply for superposing an AC voltage on the DC voltage of excitation means of the rotor winding, a field voltage detector for detecting an AC portion of the voltage of the rotor winding of an excitation circuit, a field current detector for detecting an AC portion of the current flowing in the rotor winding, an arithmetic unit for calculating the impedance of the rotor winding from the voltage and current detected from the field voltage detector and the field current detector respectively, and fault decision means for deciding a fault of the rotor winding from the value of the impedance. In this configuration, in the case where an AC voltage V is applied to the excitation circuit and an AC current I flows therein, the impedance Z_0 of the rotor winding is given as

$$Z_0 = V/I \quad \text{..... (3)}$$

In the case of an inter-layer shorting of the rotor winding where a number ΔN of winding turns out of N are shorted and become ineffective, on the other hand, the impedance Z of the rotor winding is expressed as

$$Z = Z_0 (1 - \Delta N/N)$$
$$= Z_0 - \Delta Z_1 \quad \text{..... (4)}$$

In view of the fact that an AC current is supplied by a power supply, however, there flows in the shorted number ΔN of turns of the winding such a current as to offset the magnetic fluxes generated in the sound number of turns of winding (N - ΔN) by the electromagnetic induction. As a result, assuming that the reduction in impedance due to the electromagnetic induction is ΔZ_2, the apparent impedance Z of the rotor winding is given as

$$Z = Z_0 - \Delta Z_1 - \Delta Z_2 \quad \text{..... (5)}$$

It is seen from this equation that the impedance reduction is further increased by ΔZ_2 as compared with when a DC current is supplied, thereby increasing the detection accuracy.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing a configuration of a rotor winding fault diagnosis system according to an embodiment of the present invention.

Fig. 2 is a block diagram showing a configuration of a conventional rotor winding fault diagnosis system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

An embodiment of the present invention will be explained b low with reference to the accompanying drawings.

Fig. 1 is a block diagram for explaining the operating principle of a fault diagnosis system for a rotor winding of rotary electric machines, in which a rotor winding 1 of field winding type is supplied with a DC voltage by excitation means 2 on th one hand and with an AC voltage from a power supply 10 through a transformer (DC-AC superposing means) 9 on the other. This excitation circuit includes a field voltage detector 4 for detecting the AC portion of the voltage of the rotor winding 1 and a field current detector 3 for detecting the AC portion flowing the rotor winding 1, that is, a superposed AC portion. The field voltage V_{AC} detected at the field voltage detector 4 and the field current I_{AC} detected at the field current detector 3 are applied to an arithmetic unit 5, whereby the impedance Z of the rotor winding 1 is calculated from the field voltage V_{AC} and the field current I_{AC}. The impedance Z thus calculated is applied to a fault decision means 11 for deciding a fault of the rotor winding 1. The fault decision means 11 includes a comparator 7 for comparing the impedance Z calculated with a reference impedance Z_0 of th rotor winding 1 produced from a reference signal generator 12, and a display unit 8 for displaying a fault, if any, or an alarm unit for sounding an alarm.

In this manner, the excitation circuit is supplied with the DC voltage V_{DC} and the current I_{DC}from the excitation means 2, together with the AC voltage V_{AC} and AC current I_{AC} superposed by the power supply 10. The arithmetic unit 5 produces the impedance Z of the rotor winding 1 from the field voltage V_{AC} detected at the field voltage detector 4 and the field current I_{AC} detected at the field current detector 3 as shown below.

$$Z = V_{AC}/I_{AC} \quad \text{..... (6)}$$

The impedance Z is compared with a reference impedance Z_0 from the reference signal generator 12 at the comparator 7, and if the absolute value $|Z_0 - Z|$ of the difference therebetween is larger than the reference value ΔZ, an alarm signal is produced with a fault indicated on the display unit 8. Assume that the reference impedance Z_0 is 10 ohm and the reference value ΔZ is 3 ohm, for instance, the output of the arithmetic unit 5 is given as Z = 10 ohm if there is no fault in the rotor winding. Thus,

$$|Z_0 - Z| < \Delta Z \quad \text{..... (7)}$$

In this case, the comparator 7 produces no alarm signal.

Assume that an inter-layer shorting has occurred in the rotor winding 1 and the 2-ohm portion

of the field winding 1 has become ineffective. In equation (4), Z_1 = 2 ohm, and Z = 10 - 2 = 8 ohm. In this case, if the inter-layer shorting of the rotor winding 1 were diagnosed by a winding resistance as in the conventional way,

$Z_2 - Z < \Delta Z$ (8)

and in spite of an inter-layer shorting that has occurred, the comparator 7 .whould not issue any alarm signal. According to the embodiment under consideration, by contrast, the use of the AC power supply 10 permits a current to flow offsetting the magnetic fluxes generated in a sound number of turns of winding by the electromagnetic induction, which in turn reduces the impedance ΔZ_2. If Z_2 = 3 ohm, for instance, the impedance Z of the rotor winding 1 is given as Z = 10 - 2 - 3 = 5 ohm from equation (5), and thus,

$Z_3 - Z > \Delta Z$ (9)

As a result, the comparator 7 issues an alarm signal with a fault indicated on the display unit 8.

If a disconnection causes the impedance Z of the rotor winding 1 to be $\infty\Omega$, on the other hand,

$Z_2 - Z' > \Delta Z$

In similar manner, the comparator 7 produces an alarm signal and a fault is indicated on the display unit 8.

The value ΔZ should be set with a certain margin taking a faulty operation due to noises into consideration.

In this way, the detection accuracy of the inter-layer shorting of the rotor winding 1 is improved, and the rotor winding can be diagnosed without affecting the DC excitation current I_{DC} of the excitation circuit. The diagnosis of a fault is thus possible even while the rotary electric machine is running.

The fault decision means 11 is not limited to the configuration shown in the drawings. For instance, the output of the arithmetic unit 5 may be displayed on the display unit 8 and used for decision. Also, the reference impedance Z_3, which may be set in advance, may alternatively be produced in such a manner that as shown in Fig. 2, the impedance at a given time point calculated by the arithmetic unit 5 is stored in a memory and an impedance stored a predetermined time before the given time is produced as a reference impedance Z_3 from the reference signal generator 12.

Further, the AC voltage to be superposed is preferably small so as not to adversely affect the DC excitation, or 10% or less of the excitation voltage.

It will thus be understood from the foregoing description that according to the present invention, an AC power supply means is included in the excitation circuit and the AC portion of the voltage of the rotor winding and the AC portion of the current thereof are used to calculate the impedance of the rotor winding and thus to decide whether there is a fault of the rotor winding on the basis of the impedance thus calculated, so that a highly accurate fault detection is possible by utilizing the electromagnetic induction even while the rotary electric machine is in operation.

Claims

1. A fault diagnosis system for the rotor winding (1) of a rotary electric machine comprising a rotor winding of rotary field type (1) and an excitation circuit (2, 3, 4, 9) for exciting the rotor winding (1) in DC fashion,
characterized in that an AC voltage is superposed on the excitation circuit (2, 3, 4, 9), the impedance of the rotor winding (1) is calculated from the superposed voltage value and the value of the AC current flowing in the excitation circuit (2, 3, 4, 9), and the impedance is compared with a predetermined reference impedance thereby to decide a fault of the rotor winding (1) from the magnitude of the difference between the impedance and th reference impedance.

2. A fault diagnosis system for the rotor winding (1) of a rotary electric machine comprising a rotor winding of rotary field type (1) and DC excitation means (2) for exciting the rotor winding (1),
characterized by a power supply (10) for superposing an AC voltage on the DC voltage of the excitation means (2), a field voltage detector (4) for detecting the AC portion of the voltage of the rotor winding (1), a field current detector (3) for detecting the AC portion of the current flowing in the rotor winding (1), an arithmetic unit (5) for calculating th impedance of the rotor winding (1) from the voltage and the current detected by said field voltage detector (4) and the field current detector (3) respectively, and fault decision means (11) for deciding a fault of the rotor winding (1) from the impedance calculated by the arithmetic unit (5).

3. A fault diagnosis system according to Claim 2, characterized in that said fault decision means (11) includes a reference signal generator (12) for producing a reference impedance, and a comparator (7) for comparing the impedance calculated by the arithmetic unit (5) with the reference impedance and producing an alarm signal when the difference between said impedance and said reference impedance exceeds a predetermined value.

4. A fault diagnosis system according to Claim 2 or Claim 3,
characterized in
that the magnitude of the AC voltage superposed on the DC voltage is not more than 10%.

5. A fault diagnosis system according to any of the Claims 2 to 4,
characterized in

that the reference impedance produced by said reference signal generator (12) is provided by an impedance value of the rotor winding (1) calculated by the arithmetic unit (5) a predetermined time in advance.

FIG. 1

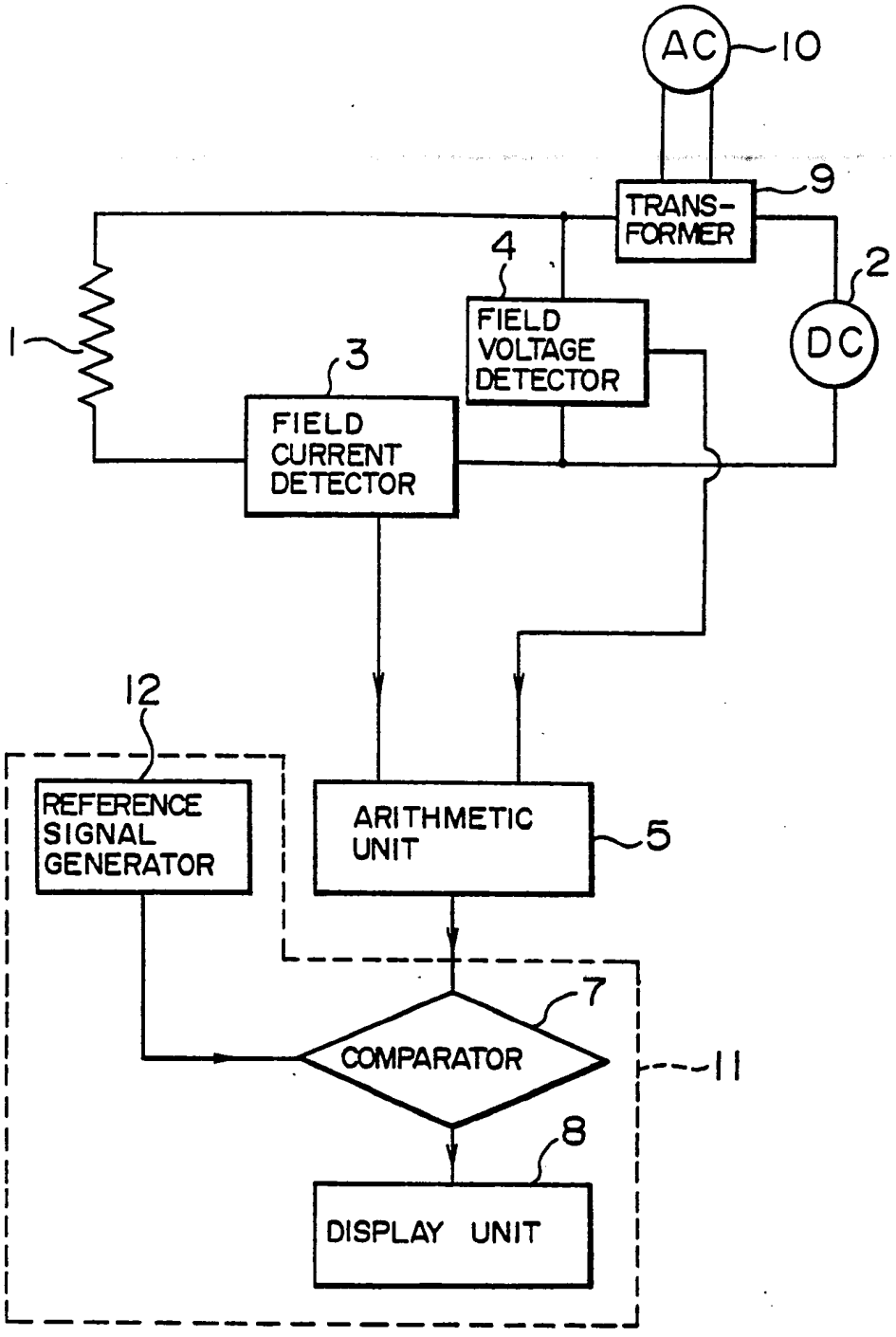
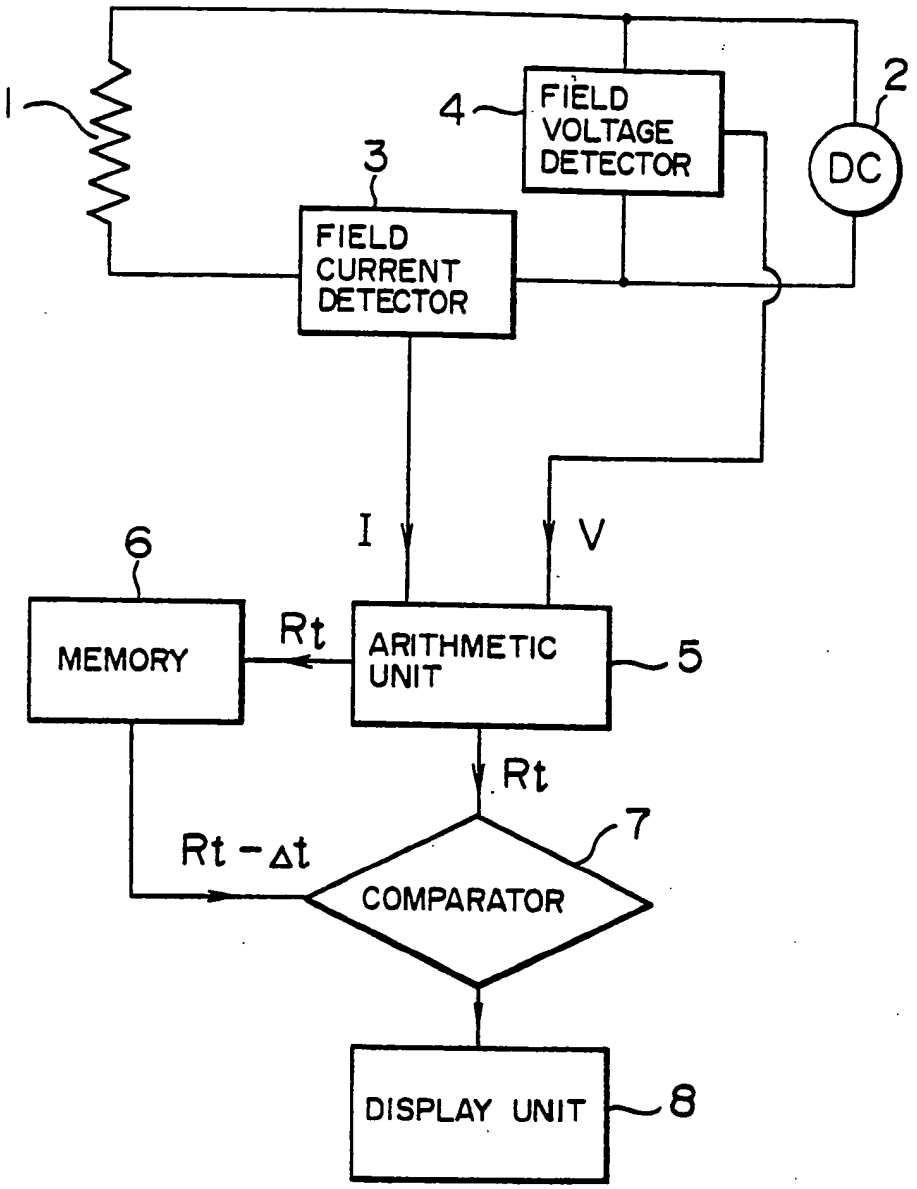

AC
10
TRANS-
FORMER
9
4
FIELD
VOLTAGE
DETECTOR
2
DC
1
3
FIELD
CURRENT
DETECTOR
12
REFERENCE
SIGNAL
GENERATOR
ARITHMETIC
UNIT
5
7
COMPARATOR
11
8
DISPLAY UNIT

FIG. 2


1
2
3
4
FIELD VOLTAGE DETECTOR
DC
FIELD CURRENT DETECTOR
I
V
6
MEMORY
Rt
ARITHMETIC UNIT
5
Rt
Rt - Δt
7
COMPARATOR
DISPLAY UNIT
8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 87 11 8560

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	DE-C- 592 728 (A.E.G.)		G 01 R 31/34
A,D	PATENT ABSTRACTS OF JAPAN, vol. 7, no. 84 (E-169)[1229], 8th April 1983; & JP-A-58 12 555 (HITACHI SEISAKUSHO K.K.) 24-01-1983		
A,D	US-A-4 377 784 (HITACHI)		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

G 01 R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	09-03-1988	HOORNAERT W.

CATEGORY OF CITED DOCUMENTS

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